Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 15 (2011) 246 – 250

Procedia Engineering

www.elsevier.com/locate/procedia

Advanced in Control Engineering and Information Science

Design of Fumigation Temperature Control System Based on Single-Chip Microcontroller

ZHANG Hai-feng*, ZHAO Ai-ling, HOU Jun

The Experiment Center, Anyang Institute of Technology, Anyang Henan 455000 China

Abstract

In order to mitigate problems such as temperature non-linearity, severe hysteresis, and large magnitude of fluctuation, we have designed a fumigation temperature control system based on AT89C52 single-chip microcontroller. The combination of improved PID algorithm and Pulse Width Modulation (PMW) technology results in whole-process fumigation temperature controlling with reduced overshoot and shortened lag time. Our test results show that the design leads to superior temperature control capability and dynamic performance. The fumigation temperature control system based on this design has very good stability and reliability, with friendly user-machine interface that allows easy operation. The circuits and programs used in the design have good versatility and portability.

Selection and/or peer-review under responsibility of [CEIS 2011]

Keywords: DS18B20；AT89C52；Improved PID algorithm；Pulse Width Modulation； Temperature control

1. Introduction

Fumigation therapy uses the vaporization of liquid Chinese medicines to produce steam that goes directly to the targeted body part of a patient. Fumigation treatment combines traditional Chinese medicine with thermal therapy, steam therapy, and Iontophoresis. Such a treatment generally shows quick curative effect with little side effects, and causes no pain to the patients. Therefore it has high promotional value in the field of health care. Temperature control is of critical importance to ensure the effectiveness of the fumigation treatment. The traditional method of manual temperature control in fumigation can result in large magnitude of temperature fluctuation. So the effectiveness of the treatment highly depends on the operator's experience, and the lack of experience often makes the fumigation therapy less efficient. In addition, the fumigation control parameters cannot be modified in real time based on the specific conditions of individual patients. In order to solve the above problems and to ensure the effectiveness of

* ZHANG Hai-feng. Tel.: 13598129033
E-mail address: ayzhaoal@126.com.

doi:10.1016/j.proeng.2011.08.049

fumigation treatments, we report in the paper the design of a microcontroller-based control system that has high accuracy, small size, high reliability, and good application prospects.

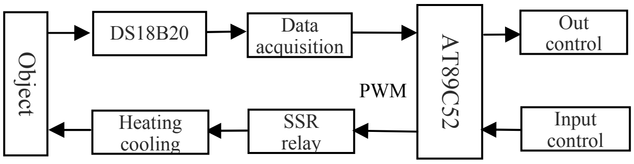


Fig.1. Architecture diagram of the temperature control system

2. System Overview

Figure 1 shows the diagram of the designed control system. It includes units such as signal acquisition, central processing, information display (LED, LCD), keyboard control, and controlled objects (heater and fan). Operator sets the value of temperature and time via the keyboard, the microcontroller AT89C52 receives data, executes the control algorithm computing using Pulse Width Modulation (PWM) technology, solid state relays control furnace heating power and cooling fan (auxiliary heat dissipation). When the temperature goes above the set point, the heating furnace is stopped, cooling fan is started to facilitate heat dissipation. When the temperature drops below the set point, heating furnace is started, and the cooling fan stopped. The system status is continuously fed to the output LED and LCD display.

3. Control Theory

Fumigation steam temperature control is a pure delay system, and is a relatively complex control object. Conventional PID control is not very effective. To further improve its temperature control performance, this design uses an improved PID control strategy.

3.1. The improved PID algorithm

In the improved PID control algorithm, differential treatment is only applied to the output data, but not to the input data. Differential output signals include target parameters and their rate of change, such signals are then fed to the PI controller to be used in overshoot prevention. The algorithm compensates the systems' hysteresis effect, and improves the performance of the overall fumigation process [1-3]. The improved PID control system has the following transfer function:

$$\frac{Y(s)}{X(s)} = \frac{G_c(s)G(s)e^{-\tau s}}{1+(T_d(s)+1)G_c(s)G(s)e^{-\tau s}} \tag{1}$$

Where $G_c(s)$ represents proportional integral controller, $T_d s+1$ is the antecedent differentiation element, $G(s)$ signifies the transfer function of the controlled object that excludes the timing lag, $e^{-\tau s}$ contains the timing lag component of the transfer function of the controlled object.

3.2. Object Control Model and PID Parameter Initialization

The object control model has been established based on a series of open-loop experiments: the default initial temperature of the system is room temperature, i.e. 20 ℃. Based on data analysis of multiple runs of screening experiments, we selected 30s as the sampling interval. Stable experimental data were then obtained and the corresponding step-response curve of temperature is shown in Figure 2.

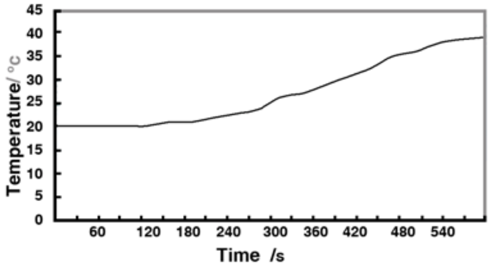


Fig. 2. Step-response curve of temperature

The PID controller parameters are extracted using a general engineering method with the following steps:

- Find the pure delay time τ of the controlled object, and the rise time constant T. Using the relation between the model parameters and the characteristic responding curve we can get: T = 240s , τ = 120s, and system gain $K = 0.5$. The reference model of the temperature control system is then:

(2)

$$G(s) = \frac{0.5 e^{-120 s}}{240 s + 1}$$

- Using the value of τ , T , and the control degree, the theoretical reference values of K_i、 T_i、 T_d can be derived from setting calculation equations of the self-regulating objects.
- The parameters established with the above method can only serve as initial reference values. Using PID control operation formula and the dispersion process, the PID algorithm is expressed as [4-5] :

(3)

$$u(k) = k_p \left[e(k) + \frac{T_s}{T_i} \sum_{j=0}^{k} e(j) + \frac{T_d}{T_s} \left[e(k) - e(k-1) \right] \right]$$

Where k is the sampling number, $k = 0, 1, 2, 3, \ldots$, $u(k)$ is the computer output value for the kth sampling, $e(k)$ is the input deviation value for the kth sampling, and $e(k-1)$ for the input deviation value of sampling number $(k-1)$ [6] .

For the temperature control system, generally the sampling interval is between 10s and 20 s. We choose 10s as the sampling period. In order to obtain better control effects, closed-loop fine-tuning is necessary. Based on the characteristic closed-loop responding data, the control parameters are repeatedly modified to achieve the best temperature control performance. When the set temperature is 40 ℃, the control parameters have been calculated to be: K_i=4.5,T_i=66.7,T_d=10.

4. Algorithm Implementation

The complete system program consists of main program, data acquisition, control and computing, and input / output / display modules. The main program is mainly used for system initialization, data processing and subroutine execution. The control/computing module performs PID operation, adjusts the PWM duty cycles, and controls the heating and cooling functions of the fumigation process. The overall block diagram of the system software is shown in Figure 3.

The workflow of the system software: When the system is powered on or reset, all modules undergo the initialization procedure. This includes initializing the stack pointer, port settings, PWM duty cycle setting, the improved PID operation and so on. Then the software and hardware modules perform selfdiagnosis, after which the timer and external interrupt are activated, and the system goes to the looping mode. When an interruption occurs, the system first looks for the interruption source. Once the interruption source is identified, the corresponding application program module is invoked to take proper reactions. After execution of the corresponding procedures, the control system always returns to the main program and starts the next loop.

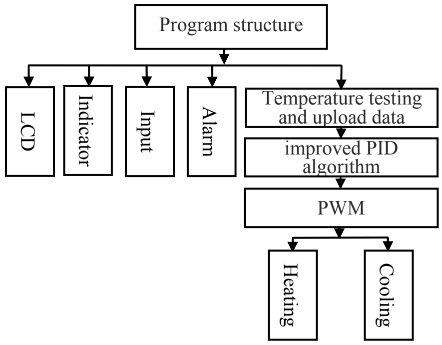


Fig.3. the overall block diagram of system software

During system program design, it is of critical importance to establish the connection between the control algorithm and the pulse width modulation technology. It can be seen from the program flow that the output from the control algorithm directly affects the PWM outputs. The maximum value of the PID operation corresponds to the maximum output of the PWM duty cycle, while the minimum value of the PID operation corresponds to the minimum output of the PWM duty cycle. In the control system the PWM period is set at 5s, and the improved PID operation results have the maximum value of 100, and minimum value of 0. The PWM duty cycle has maximum of 100% , and minimum of 0%. There is the following relationship:

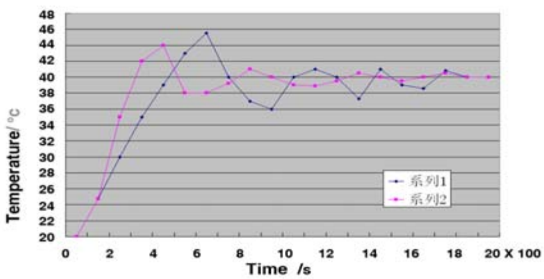
$$P = DC = (A - B)C \tag{4}$$

Where P is the system PWM value. D is the algorithm output amplitude. A and B, respectively, represent the upper and lower limit of the results of the improved PID algorithm. C is a coefficient.

5. Test results and data analysis

The improved PID control and the conventional PID control have been compared in a fumigation bed. We monitor the performance with the same initial conditions. With the initial temperature of 20 ℃, we set the required steam temperature at 40 ℃. The total measurement time is 40 minutes. Figure 4 shows the temperature curve.

Fig. 4. Fumigation bed temperature control curve.



In figure 4, curve series 1 (with dashed line) is the dynamic responding of the conventional PID control, while curve series 2 (with solid line) the dynamic responding of the improved PID control. It can be seen that the improved PID control gives significantly shorter initial heating time, and after 750s the temperature has stabilized. As time goes on, temperature oscillation frequency reduces, and the amplitude also decreases. So the divergent trend is effectively inhibited, and the temperature eventually becomes stable. The improved PID drives the temperature deviation towards minimum direction, and the system temperature stability is better than1 ℃, which is a decent performance. The improved PID control has been proved to reach the stable state much earlier than the conventional PID control.

6. Conclusions

In order to mitigate complex fumigation steam temperature control problems such as temperature non-linearity and severe hysteresis effect, we have designed a fumigation steam temperature control system that combines the improved PID algorithms with PWM technology. The test results show that this design shortens the temperature control lag time, and also reduces overshoot amount. Therefore it can significantly improve the fumigation treatment efficiency. This new design has been proved to have better temperature control performance than the conventional PID temperature control method. The fumigation temperature control system based on this design has very good stability and reliability, and meets the design requirements. The circuits and programs used in the design have good versatility and portability, and have significant application potential and high promotional value in the field of health care.

References

[1] WU Hong-xin,SHEN Shao-ping. PID control application and theory[J]. Control Cngineering, 2003,l0(1):37-42.

[2]LI Ming, HU Xian-zhi,FU Hui,HUANG Hui-juan.Researchon control ofelectric stove temperature strategy heating [J].Journal of Engineering Design,2007,14(6):482-485.

[3]SUN You-Xian,SHAO Hui-He. Control technique of industrial process(Application of chapter) [M]. Beijing: Chemical Industry Press, 2006:121-150.

[4]LIN Yian-ping,ZHOU Bao-lin. The application of a steam temperature optimized control system in thermal power plants[J]. Thermal Energy and Power Engineering, 2005,20(4):430-432.

[5] JIANG Xiao-guo,QI Shuang-xi,WANG Wei. Self-stability temperature controller of high-precision semiconductor lasers[J]. Electronics, 2002,(5):56-59.

[6] JIN Bo,ZHOU Yu-xi,NING De-sheng,WONG Zhen-tao. Network-based intelligent multi-point temperature controller base on single chip[J]. Electrical and Mechanical Engineering, 2006,23(1):12-15.